
APPLICATION OF SCIENCE TO PROTECTED AREA MANAGEMENT: OVERCOMING THE BARRIERS¹

Carolina Murcia² and Gustavo Kattan³

ABSTRACT

No other line of practice requires application of science more urgently than conservation. Here we explore several elements that must be put in place to establish lines of communication between scientists and managers of protected areas. First, it is necessary that scientists are aware of the information needs of managers, that they produce the relevant information, and that this information is available to managers. Second, it is necessary that managers not only know how to access, process, and incorporate the information, but that they also internalize their need for that science and the clear advantages of incorporating it into their practice. We propose several mechanisms to ensure an adequate flow of information between the two groups: active dialogue between the parties, translators of science located both in academia and government and nongovernmental organizations (NGOs), and execution of joint projects. In particular, we argue that science-oriented NGOs can play a major role in bridging the gap between basic science and on-the-ground conservation. We finish by describing three case studies in which some of these models have been explored in Colombia and how science has been applied to address conservation and management concerns.

Key words: Applied science, Colombia, conservation, management, nongovernment organizations.

"Science does not provide the solutions, but it can help understand the consequences of different choices."

—Lubchenco (1998)

Science is expected to play a major role in informing and implementing decision-making processes that affect civil society, because science provides a rigorous and objective knowledge framework (May, 1998; Mills & Clark, 2001; Eagle et al., 2003; Manning, 2005; Roux et al., 2006). In this context, no other line of practice requires the application of science more urgently than the conservation of biodiversity, in which policies and decisions could have tremendous implications for all forms of life. Yet, the broken lines of communication to transfer this knowledge between scientists and conservation policy makers and managers is a permanent concern of parties involved in conservation worldwide (Pendergast et al., 1999; Stone, 2002; Pullin et al., 2004; Meijaard & Scheil, 2007). This concern is particularly worrisome in tropical developing countries, because they harbor the greatest proportion of biodiversity but lag behind developed countries, both in absolute and relative terms, in monetary resources and

highly trained scientists and managers. Lack of communication leaves valuable information trapped in specialized journals, with no application, and those making important decisions are deprived of critical information.

Scientific knowledge can be applied to the conservation and management of biodiversity at multiple levels along a great continuum—from the president and high-ranking politicians of a nation to the local park warden. Each level deals with issues that operate at different spatial scales, with different degrees of detail. The professional profiles of the users of scientific information are different, and so are the mechanisms for incorporating science into the decision-making process. Here we will focus on what we perceive as one of the most critical levels: the middle managers, in particular those involved in the management of protected areas. These managers are typically staff members in national or state government environmental agencies and are the people who make the day-to-day decisions on how to manage the parks; they are responsible for devising and implementing management plans for areas and species.

¹ We wish to acknowledge the Wildlife Conservation Society and The John D. and Catherine T. MacArthur Foundation for supporting the involvement of the authors in several of the processes described. The work presented here was also supported by the Colombian National Parks Unit and Corporación Autónoma Regional de Risaralda. This manuscript benefited from the comments of Javier Mendoza, Victoria C. Hollowell, Peter Jørgensen, and an anonymous reviewer.

² Fundación EcoAndina, AA 25527, Cali, Colombia, and Organization for Tropical Studies, Apartado 676-2050, San Pedro, Costa Rica. carolinamurcia01@gmail.com.

³ Fundación EcoAndina, AA 25527, Cali, Colombia, and Pontificia Universidad Javeriana, Departamento de Ciencias Naturales y Matemáticas, Cali, Colombia. gustavokattan@gmail.com.

doi: 10.3417/2008031

To incorporate scientific knowledge into the practice of conservation, several elements are necessary. First, the relevant knowledge needs to be available. This availability requires that scientists address specific conservation and management issues in their research, and that the information is accessible by managers. Second, managers must have some incentive, or mandate, to base their decisions on sound science. Third, managers need to have the training and the time to access the scientific literature, extract the relevant information, and incorporate it into their action plans, within an adaptive framework that would allow them to evaluate options, as well as revise and adjust their decisions. Finally, the two groups need to be able to communicate effectively, to ensure that information is properly applied, and to provide feedback to scientists on the information needs of decision makers and managers.

In this article, we explore whether these conditions are being met, identify the elements that condition the generation and use of information, explore how these elements are connected by information pathways and affected by external factors, and find the gaps. We also illustrate several case studies in Colombia in which science has been applied to conservation planning using different strategies. We argue that science-oriented nongovernmental organizations (NGOs) can play a major role in bridging the gap between basic science and on-the-ground conservation. Although this paper is based on our experience in Colombia, we believe that it reflects the reality of many other Latin American countries. We focus on the biological sciences, but the situation is likely to be similar for the social sciences.

INFORMATION NEEDS OF MANAGERS

There is a tremendous amount of scientific knowledge pertaining to biodiversity and conservation that is published in journals. This knowledge is valuable and potentially usable by the conservation community in developing countries. However, the successful application of this science to management needs to account for the following premises.

SITE SPECIFICITY

Conservation problems are site specific, involving unique biological landscapes, varied human cultures with their own local idiosyncrasies, and particular sets of economic conditions and interests. Ideally, solutions for a site's conservation problems should be devised using locally produced information, but few sites across the tropics have a local research program. One option is to extrapolate data from similar sites or

ecosystems, but that is not without risk. Doing so requires an in-depth knowledge of the particular ecosystems, landscapes, or organisms to which this information would apply, so that reasonably reliable predictions on how the system will respond can be made. The more ecologically different the sites are from those where data have been generated, the less reliable and effective that extrapolation will be. For example, extrapolating the impact of edge effects from what we know about lowland tropical rainforests in Amazonia to high-elevation humid forest in the Andes would be less accurate than an extrapolation to other lowland humid forest sites. Any extrapolation constitutes a working hypothesis that needs to be tested. Monitoring of any management implementation is a basic tenet of the concept of adaptive management, in which the results of the prescribed action are recorded and compared to the expected behavior, and corrective actions are taken to redirect the management to yield the desired effects (Walters & Holling, 1990; Johnson, 1999). Therefore, the application of science generated under different circumstances does require an additional component of monitoring.

CONSERVATION PROBLEMS PERSIST BEYOND THEORETICAL FADS

Some issues that are pertinent to management and conservation today were investigated several decades ago. However, before some key aspects were fully explored, scientists moved on to search for newer ideas and other knowledge frontiers. For example, subjects such as tropical secondary succession and gap dynamics were not studied in sufficient detail, and across different ecosystems and spatial and temporal scales, to give managers the adequate tools to address specific issues such as habitat restoration or the effects of selective logging. While some issues are being revisited under new conceptual frameworks (Guariguata, 1998; Chapman et al., 1999), numerous practical questions remain unanswered (Guariguata & Ostertag, 2002) and managers depend on those answers today to manage fragmented and disturbed landscapes. For example, how do wet tropical forests change during the middle to late successional stages (i.e., > 50 years old; Guariguata & Ostertag, 2002; Chazdon et al., 2007), and how long do the advanced successional stages last (Chazdon et al., 2007)? What is the average turnover rate for different tropical ecosystems? Given natural rates of disturbance and regeneration, what would be the minimum conservation area of a given tropical ecosystem to ensure long-term persistence? What are the successional patterns of different animal communities in middle to late successional stages? What are the barriers to

recolonization for different animal groups? If these questions remained unanswered for lowland wet tropical forests, where most tropical research occurs, there is less information for other ecosystems, such as dry, montane, or high-elevation ecosystems.

LONG-TERM COMMITMENT TO A SITE OR ISSUE

Many conservation problems require long-term or continued monitoring of a system to understand the nature of its internal dynamics. Such is the case of canopy trees that have supra-annual phenological patterns (Newstrom et al., 1994; Chapman et al., 1999) or of mammal and bird species with low fecundity and long life expectancy. Management plans that involve these species require information on the frequency of the flowering or fruiting events, plus some indication of the factors that trigger flowering or, in the case of the animals, the frequency of reproduction and number of reproductive years of an animal to estimate overall fecundity. Such information can be attained only after many years of monitoring. However, few sites in the tropics enjoy the benefits of a long-term research program. For example, Brazil, a country of 8 million km², has only 12 sites recognized by the International Long-term Ecological Research Network as long-term sites (<<http://www.icb.ufmg.br/peld/>>). Of those sites, only one is in the Amazon forest.

FACTORS THAT AFFECT THE GENERATION OF APPLIED RESEARCH

A survey conducted among conservation leaders found a general perception that academic research does not meet the needs of conservation practitioners (Meijaard & Scheil, 2007). The generation and application of science into management for conservation has two main elements: the scientist and the manager. Both are affected by a number of factors that modulate how the science is produced, transferred, and applied (Fig. 1). On the scientist's side, the factors that affect selection of research topics and where this research is published are: the sources of funding, the scientists' own intellectual interests, the scientists' institutional criteria for professional advancement, and the policies of publishers of scientific papers. On the manager's side, the factors that affect whether they access and apply science to their own decisions are: the policies from their own institutions regarding how much they expect science to be a part of the process and how many resources they provide managers to that end (e.g., time, funds, library access), their own training, and the sociopolitical context in which these decisions are made.

SELECTION OF RESEARCH TOPIC

Several internal and external factors affect how scientists choose the topics for their research. The first two factors are of a personal nature. First, and most obvious, is the researcher's own curiosity and passion to understand a specific system. While some researchers prefer to focus their research on more theoretical questions, others are increasingly more interested in addressing questions that could have direct application to conservation issues (e.g., see Kremen, 2005). The second motivation is professional advancement. Successful research on cutting-edge topics that generates many highly visible papers can be a significant boost for a career, involving promotions or better salaries. In public Colombian universities, a faculty member's salary within a given rank is determined in part by his or her publication record. Promotion to higher ranks is also determined by productivity. Thus, there is an incentive for searching for topics that can produce papers in top journals.

A third factor that affects topic selection is funding. Funds can come as grants from private donors or science government agencies or as contracts for commissioned work from environmental government agencies. Funding is also driven by fierce competition and by the priorities set by funding agencies and other donors. To secure funding from science funding agencies, proposals need to show how much science will be advanced. Thus, proposals that address cutting-edge issues and push the frontiers of science are more successful; however, Colciencias, the Colombian government research granting agency, requires a statement of social pertinence in proposals. Donors are likely to avoid sensitive questions that could generate bad press or conflict (Meijaard & Scheil, 2007). This tendency precludes research that addresses threats caused by highly visible or identifiable corporations. Donors also tend to shift their programmatic emphasis frequently enough to make it hard for scientists to sustain long-term monitoring or research. To ensure continuance of funding that would allow the compilation of long-term data, scientists must exhibit great ingenuity to keep presenting the same system under a novel conceptual light at each new funding cycle.

A more recent source of funding that has the potential to engage scientists in answering applied questions through research is through contracts with environmental government agencies. Although a rare occurrence, progressive regional environmental agencies in countries such as Colombia (e.g., as Corporación Autónoma Regional de Risaralda [CARDER], Corporación Autónoma Regional del Valle del Cauca

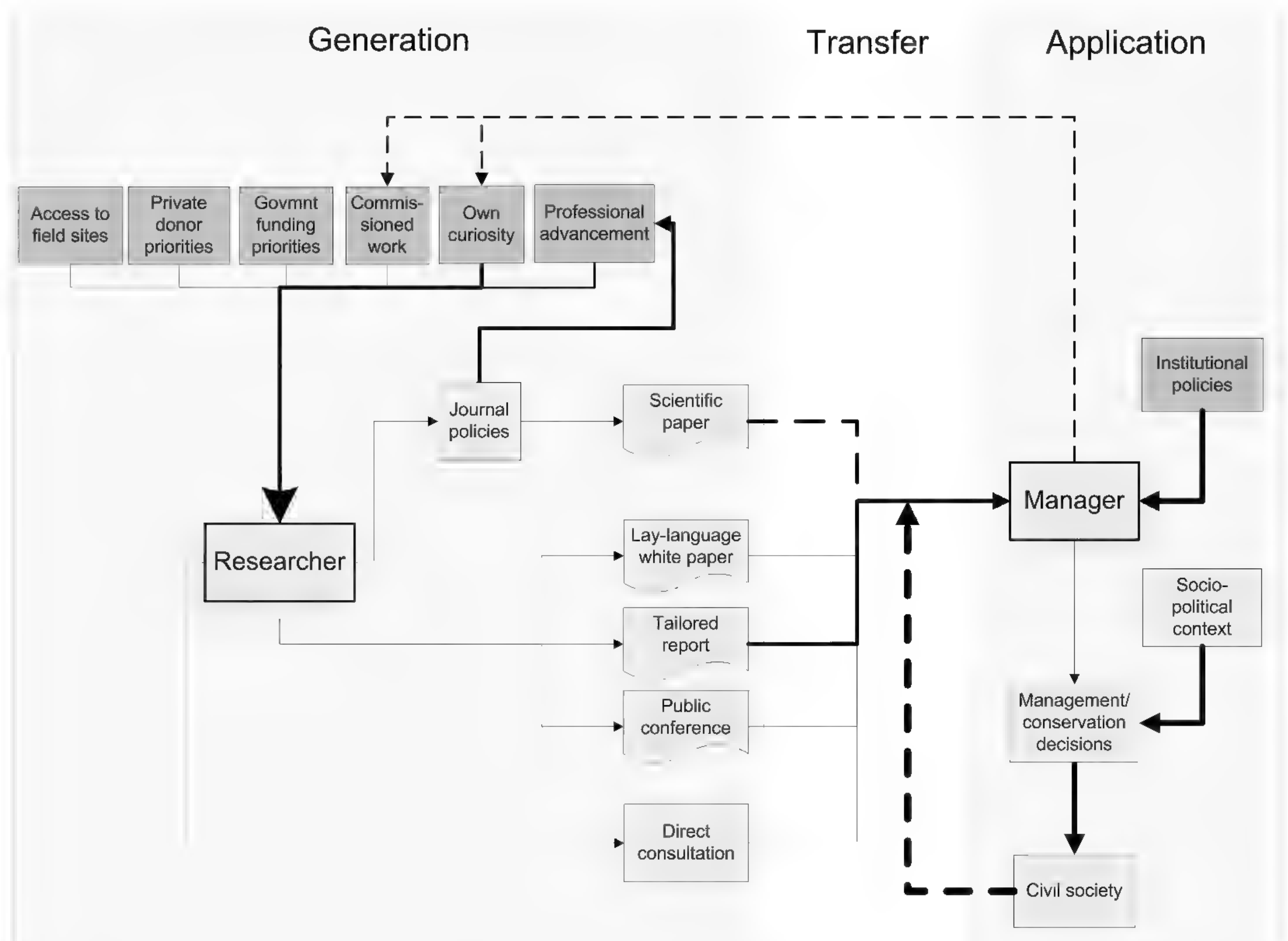


Figure 1. Pathways describing the three-step process of (1) generation of knowledge that may be applicable to management of protected areas, (2) transfer of knowledge, and (3) application of knowledge. The steps of generation and application are framed circumscribing the field of action of the two main actors (researcher and manager). In contrast, the second step (transfer) has been left intentionally without boundaries or an associated actor to illustrate that this is an area that is currently a no-man's-land, and that each actor expects that the other assumes the related responsibilities. Boxes in dark gray show the factors that affect each of the two actors. Line thickness illustrates our perceived strength of the relationship. Broken lines indicate weak links.

[CVC], Corantioquia) routinely outsource short-term research projects to address specific information needs.

Finally, limitations inherent to a field site also affect topic selection. To address conservation issues, scientists often need to work in protected areas, which involves obtaining research permits from the appropriate agencies. A lack of clear procedures by the environmental authority or highly complex processes makes it difficult to obtain these permits and discourages researchers from these areas and research topics. When issues involve local communities and several implementing agencies, two additional levels of complexity are added. Seeking agreement among actors, and accommodating their participation in the project, is a diplomatic art in which few scientists are trained, although a handful of new schools are gradually training scientists in these multidisciplinary, multicultural exercises (Gibbons et al., 1994). Interestingly, some private landowners have become

interested in having research conducted on their properties (e.g., for conserving populations of red howler monkey *Alouatta seniculus* L. in the Cauca Valley of Colombia; Valderrama & Kattan, 2006). Although these landowners do not derive a direct benefit and often contribute resources in-kind, their curiosity about their own systems opens this unexpected opportunity. The availability of a permit-free and conflict-free site, where sometimes the logistics are provided or facilitated, has recently lured a number of Colombian scientists to explore conservation and ecological issues in agroecosystems.

BRIDGING THE GAP BETWEEN SCIENCE AND MANAGEMENT

Scientists in general can become rather self-absorbed. Most scientists are trained in the tradition of defining research questions from within the academic domain (Gibbons et al., 1994). In this tradition, scientists often do not consult outside of

academia about the types of questions that are relevant to pursue. Instead, they are driven by the pursuit of objectivity, replicability, and rigor in the experimental design. This approach, while commendable, leaves scant room for scientists to investigate questions essential for other interest groups, such as conservation managers. A new trend defining the focus of science is emerging (Gibbons et al., 1994) and involves a more multidisciplinary approach that integrates the academic domain with the rest of the world, frames the question in a practical problem that needs a solution, and engages other actors in the formulation of questions. Although this model has potential risks (e.g., the researcher loses control of the project), it increases insight and applicability of the recovered information and also increases accountability to all parties involved.

Nevertheless, the burden of reaching out to the other party cannot be placed solely on the scientists' shoulders. Communication between scientists and managers has to flow in both directions, and managers need to reach out to scientists (Fig. 1). Managers in developed nations are already addressing the scientific community at their own forums (Ruth et al., 2003). Unfortunately, this is not happening yet in Latin America. There is a need to create a culture among managers to attend scientific meetings and address the scientific community to present their needs for information.

Funding agencies can also help to bridge this gap. By giving priority to proposals that have a significant applicable component, government funding agencies can stimulate intranational research that answers management questions. While funding research is not usually a priority for private donors, these donors are also playing a role in shaping the interests of scientists by funding research that is directly connected to conservation issues and has immediate application (Stone, 2002).

Although managers or government agencies typically have no money and therefore no influence on how research is focused, a few progressive government agencies in Colombia that have enough resources are commissioning work from scientists on specific topics. Usually, those contracts are geared toward the assessments of biodiversity or the conservation status of species or ecosystems. As such, they are not aimed at testing cutting-edge scientific hypotheses, but at generating information required for immediate application by the agency. However, some scientists are able to design their studies in a way that merges with hypothesis-testing exercises. In these cases, it is a win-win situation: the agency obtains the information it needs and the scientist obtains funding for publishable research.

CAN MANAGERS ACCESS AND USE SCIENTIFIC KNOWLEDGE?

Applying scientific information to management and conservation takes two distinct steps: the transfer of the information and the actual incorporation into management plans and actions. These steps have different limitations and potentially different actors. The first step begins with the scientists who produce documents that summarize the questions asked, the results, and the implications (theoretical or applied) of their results. Accessibility to the documents varies depending on the type of publication chosen by the scientist.

VENUES FOR PRESENTING RESEARCH RESULTS

Given a choice, scientists prefer to publish in prestigious journals (Aarssen et al., 2008) to advance academically or increase their salaries. Papers in high-impact journals bring visibility, access to more funding, and prestige. However, the collegial competition to get an article published in those journals has exponentially increased in the past few decades and has resulted in a narrowing of the editorial criteria for accepting manuscripts (Meffe, 2006; Aarssen et al., 2008). The competition among international scientific journals is fierce (Olden, 2007), and only manuscripts that appeal to the greater scientific audience may be accepted. Therefore, journals favor articles addressing cutting-edge issues that require a conceptual development of broad implications and new methods. In addition, journals may be especially biased against manuscripts with a local emphasis, written in languages other than English, or with descriptive or applied undertones (Meffe, 2006; Olden, 2007). While this may seem unfair at first glance, one must not lose sight of the fact that these journals are responding to market forces of a distinct sector of the scientific population: academics in developed countries (Lawler et al., 2006). Although the number of journals with an applied emphasis has increased exponentially in the past 20 years (Lawler et al., 2006), the applicability of research results to different sites, ecosystems, or situations that are not central to the articles has not necessarily increased (Stinchcombe et al., 2002; Pullin et al., 2004; Lawler et al., 2006; Armstrong & McCarthy, 2007). Nevertheless, the selection pressure generated by journals can reinforce a scientist's determination to focus on cutting-edge issues and stay away from more applied topics.

Less frequently, scientists produce reports in lay language, such as in white papers, working papers, or gray literature. Reports are usually the result of commissioned work and are tailored to suit specific needs of government agencies. These types of documents are assigned a lower value as intellectual

production in academic institutions because they are not peer-reviewed documents. In addition, scientists require special skills to communicate effectively to a general audience. Therefore, there is little incentive for this type of work, except perhaps as extra income.

Faculty are often invited to present their research to general audiences as guest speakers of public events, and this makes some of their research accessible to managers. However, this is often an opportunistic activity and not part of a concerted effort to systematically transfer the information to the conservation practitioners. Often, the interaction with the scientist ends at the end of the talk.

ACCESSIBILITY OF THE INFORMATION

Once the information is published, in theory it is available for people to use; in Latin America, however, this is not a valid assumption. Managers of protected areas in Latin America typically have a professional degree (B.Sc. or B.A. equivalents) and have limited exposure to scientific research. While many are trained in biology or related disciplines, a large proportion have engineering, administration, or social sciences backgrounds. Normally, parks have management plans that outline strategies to address their particular problems, but managers may have to take specific actions in their day-to-day jobs, ideally informed by science. Park managers face a myriad of conservation problems. For many of these issues, there may be sufficient research published in scientific journals that addresses these problems from theoretical or practical perspectives, but this does not resolve the question of how a manager locates and identifies the relevant information and applies it to specific cases.

The first barrier faced by the manager is time to conduct a literature search. This issue affects managers even in developed countries (Pullin et al., 2004). Government agencies are usually understaffed, and their managers are overcommitted. Therefore, there is little time to devote to an activity that, by its very nature, is time-consuming. Although web-based, free tools such as Google Scholar (<<http://scholar.google.com/>>) have made literature searches much easier, managers still require time to read through the potentially hundreds of results for any particular query.

Information needs to be accessible—physically, linguistically, and conceptually. Physical accessibility has improved in the past decade. The widespread use of the Internet has lessened the physical gap between readers and journals, with information theoretically at anyone's fingertips. Although most electronic journal subscriptions remain expensive, managers in Colombia find their way around this obstacle by requesting articles directly from the authors or by obtaining them

from colleagues with better library access. Posting articles on authors' web pages certainly facilitates fast access to many papers.

The second component of accessibility is language. Most scientific papers are written in English, and Latin American managers are rarely fluent in this language. A survey of the conservation-relevant scientific literature produced in Indonesia since 1884 (284 documents, including 81 from the gray literature) showed that only four articles were in Indonesian, 95% were in English, and the rest were in Dutch, French, and German (Meijaard & Scheil, 2007). In time, electronic publishing should make the publishing of papers in different languages affordable.

The third component is the specialized language used in the scientific literature. A manager who is starting to learn about a specific topic faces the challenge of learning a new vocabulary, new concepts, and new methods. Costs of publishing have forced journals and authors to compress papers, thus limiting explanations to those uninitiated in the field. Clearly, managers in Latin America and other non-English-speaking, developing countries require a medium of communication that eliminates all of these barriers.

PROCESSING AND EXTRAPOLATION OF SCIENTIFIC INFORMATION

Assuming the barrier of accessibility is solved, managers need to process the information and extrapolate it to adjust it to the local conditions of their site. Managers usually receive complementary on-the-job training to improve their administrative skills and broaden their capacity to tackle a diverse array of problems. Courses may include tools for management, such as business or natural resources administration, conflict resolution, or social sciences. None of these courses improve the manager's skills to survey the scientific literature in conservation biology, much less to critically assess what is most relevant or best qualified for their particular area or situation. These limitations are solvable, but this solution requires the impetus of the government organizations and the political will of policymakers.

More importantly, managers must have a serious motivation to incorporate science into their decision making. At this time, there is no mandate that requires managers to do so. In some Colombian environmental institutions such as the National Parks Unit and several corporations (regional government environmental agencies), there has been some gradual effort to ensure that management decisions are based on solid scientific work, but it is frequently done without the resources and expertise required to do it properly. Large discrepancies exist among agencies and even countries as to the amount of science they incorporate in their work.

Although park siting still occurs in an opportunistic way in many countries, Mexico is now basing its conservation planning on an extensive nationwide database of biodiversity distributions. The next big step is to oversee that science is correctly applied.

In any market-based society, those who improve the quality of their product and its fit to society's needs are most likely to succeed. Concurrently, to the extent that managers incorporate science into their planning and decision making, they are more likely to yield a good product for the ultimate consumer: society at large. However, results-based incentives to incorporate science may take one or two generations to have an effect. The difference in the results between those who apply science and those who do not will not be apparent for several decades, and there is no time to waste. Therefore, we need to seek mechanisms that force a change in mindset among managers and decision makers, and at the same time provide the resources for managers to tap into the existing science.

THE NEED FOR A SCIENCE TRANSLATOR

Thus far, we have analyzed some aspects of knowledge generation and application, but there is one issue that requires further analysis. Whose responsibility is it to ensure that science is transferred? Is it the scientists' or the managers' responsibility to do such translation (Stone, 2002)? Currently, both groups are suffering from overextending their reach. Scientists often struggle with guilt that they are not sufficiently reaching out to other groups to ensure that their science is applied (Whitten et al., 2001), but they rarely have the time, mechanisms, or training to do so. A few scientists, such as E. O. Wilson or Bernd Heinrich, are blessed with the natural ability to communicate outside of their particular academic circle. Ironically, these scientists commonly reach out to the general public, but rarely to the managers and policy makers, perhaps because of differences in receptivity among these groups. As we have seen, managers are also overextended and lack the training to find, read, process, and synthesize the literature to apply it to specific circumstances. Even in countries such as the United Kingdom, managers tend to rely on other sources of information, rather than the primary scientific literature, to develop their management plans (Pullin et al., 2004).

We propose that there is a need for a science translator to bridge that gap; such an individual could be housed either in scientific institutions (as an outreach element) or in government organizations or science-oriented NGOs (as an official science translator and liaison with academia). To this end, a number of non-mutually exclusive mechanisms can

be devised to ensure proper transfer of science into policy and management:

1. Management organizations create an internal position of science advisor or coordinator. The primary responsibilities of this position would be to ensure that the most critically needed research is conducted in-house (in association with universities, research institutes, and research NGOs) and that the results of this and other research produced outside (i.e., in other systems or countries) are incorporated into management plans.
2. Management organizations hire consultants—on a need-to-know basis—among the scientific community to address specific issues.
3. Management organizations team with universities and NGOs and jointly develop a research agenda or policy documents that incorporate science into planning and action.
4. Management organizations form consortia with universities, research institutes, and research NGOs to address specific conservation or management issues.
5. Professional organizations, academia, or NGOs conduct training and discussion workshops that bring scientists and managers together. The goal of these workshops would be to bring new scientific advances to the attention of managers and to provide an opportunity for managers to indicate to scientists the types of issues for which they need information.
6. University professors steer graduate students toward conducting applied research in concert with government agencies and NGOs.

Variations of some of these models have been successfully tried in Colombia. We will describe three case studies in which such efforts are being made with a remarkable positive effect on the quality of the conservation decisions made later.

CASE STUDY 1: ASSESSMENT OF INFORMATION AVAILABILITY AND NEEDS IN THE COLOMBIAN NATIONAL PARKS

In 2000, the Colombian National Parks Unit commissioned the design of a research strategy in conservation biology that addressed the needs of protected areas (Kattan & Murcia, 2001; a parallel process was conducted for social sciences). This strategy was accomplished in two phases: a diagnostic phase and a collective construction phase. The diagnostic phase involved assessing the scientific information available and its accessibility, as well as the infrastructure available for conducting research in national parks. The collective construction phase involved two components: (1) a training workshop to

update area managers from all the parks in key concepts of conservation biology and (2) a series of exercises to determine the most urgent information needs to address the most critical threats in their parks.

The information diagnostics evaluated the historic output of research produced in the Colombian National Parks between 1975 and 2000. A total of 726 documents representing scientific papers (published in national or international journals) as well as gray literature (theses and technical reports) were analyzed. Of these documents, 91% fell into the category of basic research, 8% assessed effects of human activities, and 1% addressed restoration of species and ecosystems.

We also evaluated the accessibility of the documents. All reports were stored in a main library at the National Parks Unit headquarters in Bogotá, but the collection of theses and other documents was incomplete at this library. Half of the published documents were accessible because they were in local journals or in international journals with wide distributions in Colombia. The remaining half were published in international journals that were not easily accessible in Colombia. Half of the papers were in Spanish, the remainder were in English, and one was in German.

From the parks-wide consultation for the types of management issues that they were facing, park staff identified seven main themes that urgently required research:

1. Basic information on composition, structure, and dynamics of key animal and plant communities (mainly vertebrates and some invertebrates for marine ecosystems) and on the dominant ecosystems in each park
2. Basic information on habitat use, habitat availability, population status assessments, and demographics of focal (flagship, endemic, and threatened) species
3. Rates of transformation of landscapes and ecosystems
4. Impact of resource extraction (timber and nontimber products, wildlife, and mining)
5. Carrying capacities of the systems to sustain ecotourism
6. Impact of external threats such as development projects in the immediate vicinity of the parks
7. Restoration (guidelines, protocols, and species recommended)

This exercise revealed that the range of issues faced by the parks is wide and covered almost all of the current issues addressed in conservation biology at the supraorganism level. The information available at the time was not sufficient to address those issues (research output was an average of 0.6 articles per park per year). There was a dramatic decoupling

between what was being researched and what the managers needed. Only the first category (basic information on communities and ecosystems) was being partially met, because there was little information on dynamic processes at the community and ecosystem level. Accessibility of the information needed to be addressed by ensuring that all researchers turned over the products of their investigations and that the main and regional libraries were fully stocked with copies of these documents.

As part of this activity, 40 Colombian park managers received their first-ever training in basic principles of conservation biology. This training allowed them to put their management concerns in current conceptual frameworks and increased their understanding of jargon and concepts in the literature. The training also familiarized them with a selection of classic scientific papers that had become common knowledge for the average biology student in the country but were not accessible to the managers.

The following recommendations ensued from this consultation:

1. Create a full-time position of scientific coordinator (preferably Ph.D. level) within the parks unit who would define research priorities and serve as a science translator for the managers. This position could be either a permanent employee of the unit or a position filled by university faculty who would serve two- to three-year service cycles.
2. Develop an outreach policy to engage university faculty with conservation expertise in planning and management consultations. Alliances with universities and research NGOs will be necessary.
3. Streamline and clarify the process to grant research permits.
4. Develop a more efficient way to recover, store, and access the information produced by scientists in the national parks of Colombia.
5. Improve facilities to attract scientists to conduct research that is relevant to the parks.
6. Create several research stations in selected national parks.
7. Change the National Parks Unit policy to include research as one of its mandates.

Eight years later, some of these recommendations have been put into place. Research is now recognized as a more important activity, there is a science coordinator position (but not at the Ph.D. level), several national parks have research stations being run in coordination with other organizations, there are clearer procedures in place for processing research permits, and academics and other scientists are often invited by the parks unit to participate in defining new management plans.

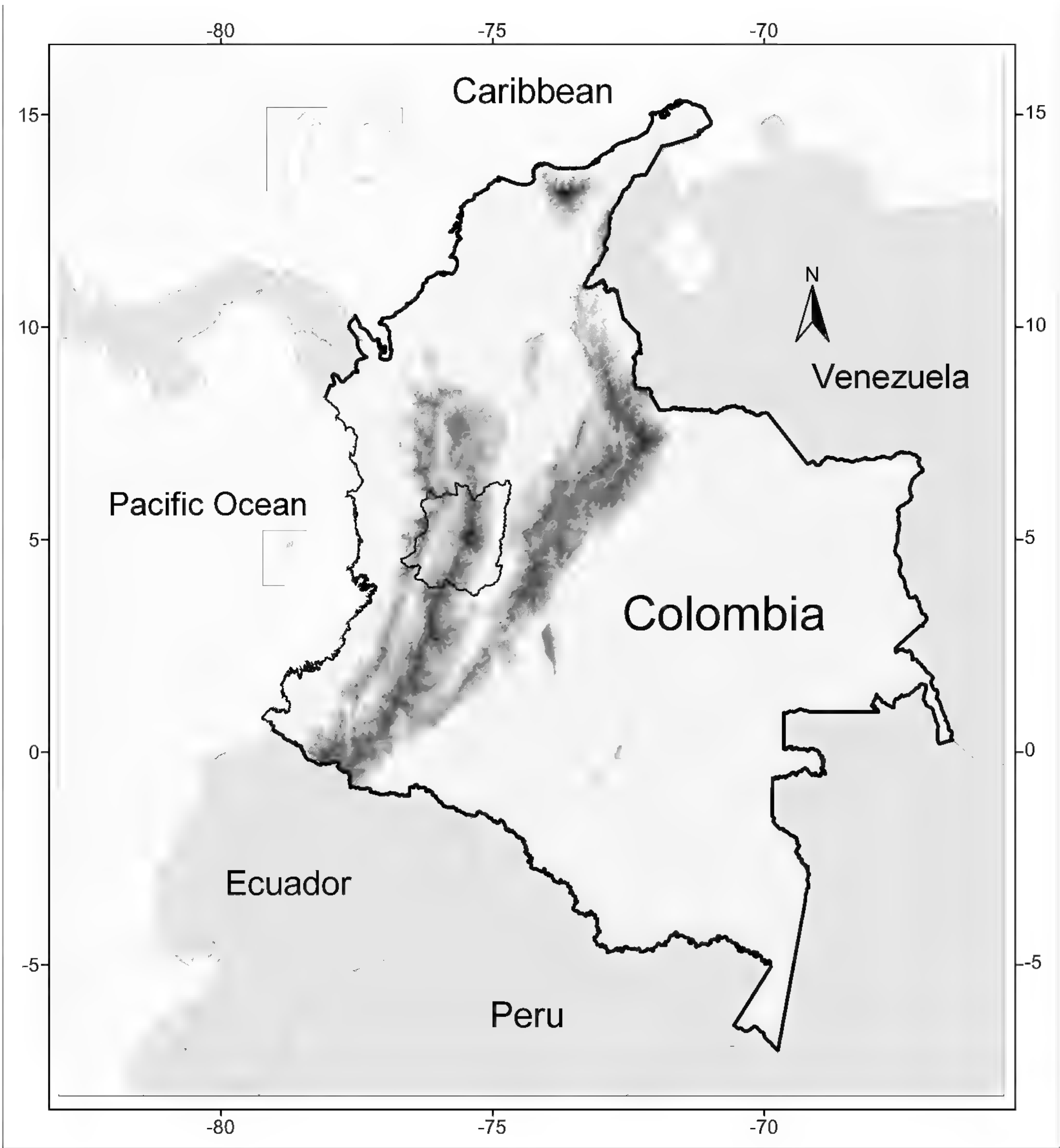


Figure 2. Topographic map of Colombia showing the location of the SIRAP Eje Cafetero (dark line).

CASE STUDY 2: DIRECT APPLICATION OF SCIENCE TO
CONSERVATION PLANNING: THE CASE OF THE SIRAP
EJE CAFETERO

One of the commitments acquired by the Colombian government in the Rio Convention was the creation of a national network of protected areas (Sistema Nacional de Áreas Protegidas [SINAP]). Colombia chose to do so in a modular fashion, with the creation of regional systems of protected areas (Sistema Regional de Áreas Protegidas [SIRAP]) that would

eventually make up the nationwide network. The first region to take on this task in 2000 was the Eje Cafetero (EC), the coffee-growing region located in central Colombia (Fig. 2). This area is 30,000 km² and encompasses portions of two Andean ranges and two inter-Andean valleys, as well as the core of the coffee-growing landscape of the country. Middle elevations (1200–1800 m) of this highly productive agricultural landscape include coffee plantations (shaded and nonshaded), pastures (for small-scale, intensive cattle ranching), other minor crops (mostly

fruits and vegetables), and forest remnants, as well as four provincial capitals (each with 300,000 to 750,000 inhabitants) and small towns. Although the area is called the Eje Cafetero, land use in the lower elevations (below 1200 m) includes cattle ranching and crops such as sugar cane. Upper elevations are less populated, and only a few crops, such as potatoes, and cattle ranching constitute the agricultural element. The rest of the area is covered with forest remnants, páramo (high Andean alpine-type vegetation), snowcaps, and exposed soil above the tree line. The rich volcanic soils and pleasant weather have sustained a dense population since pre-Columbian times, and the region is currently traversed by numerous roads that connect a prosperous network of rural settlements. In this context, the original forest has been reduced to a lattice of forest fragments, relegated mostly to elevations above 2000 m. Less than 10% of the original forest is now protected within three national parks and a few regional and municipal protected areas. The general objectives of the SIRAP-EC project were to increase the area under protection and, by doing so, to conserve a representative and viable sample of the region's original biodiversity (Kattan, 2005, 2006).

To accomplish this, a consortium of 12 institutions including five regional government environmental agencies (called Regional Autonomous Corporations in Colombia), the National Parks Unit, the Humboldt Institute (the national biodiversity institute), three Colombian NGOs, and two international NGOs was formed. Three NGOs (Fundación EcoAndina, Wildlife Conservation Society [WCS], and World Wildlife Fund [WWF]) led this consortium on the technical aspects of the biological planning phase. This phase involved: (1) defining the goals and objectives of the SIRAP-EC (i.e., defining what and how much we wish to conserve), (2) compiling spatial information and generating potential and current vegetation maps, (3) compiling a database of all biodiversity records in the region, (4) conducting biological information and conservation gap analyses as well as some rapid biodiversity inventories, and (5) recommending new protected areas.

This work was collaborative and all of the aforementioned organizations actively participated in the workshops and meetings. However, different organizations played different roles: EcoAndina, WCS, and WWF were in charge of conceptually steering the biological planning phase, compiling the information, performing the analyses, conducting a consultative process with experts, and proposing management strategies to gain functional regional connectivity. The WWF provided the training in geographic information system (GIS) to technicians at the corporations and NGOs, conducted some of the GIS analyses, and

supervised the final GIS steps. The role of the government organizations was to coordinate the project, steer the project in the social and political arenas, process the geographic information in their areas (under WWF's supervision), assist in the collection of biological information, link the SIRAP-EC to other regional processes (e.g., ecoregional planning, social initiatives, disaster prevention, and the SINAP), and generate support in the process at high levels of regional and national decision making in preparation for the final proposal of protected areas. In addition, experts from different universities, NGOs, and other government institutions were asked to contribute to several planning workshops, or hired to prepare some of the sociological analyses that framed the SIRAP-EC. The vision, project goals, selection process of candidate areas and focal species, and identification of key conservation areas were generated collectively by all of the organizations in a consultative exercise that also involved national and regional scientists.

Some accomplishments of this process include the following:

1. A proposal to increase the cover of protected areas in the region of the EC, based on the four-R principle: representation, resilience, redundancy, and restoration (Groves, 2003: 30–33). Sixty-four additional areas were selected for conservation that would increase the area under protection from 200,000–700,000 ha. (or approximately 23% of the region). Several areas have already been granted protected status. This component incorporated the latest scientific advances in reserve network design.
2. Development of management plans for focal species. Initially, seven species were selected for developing science-based management plans. The first two, the Cauca guan (*Penelope perspicax* Bangs) and the red howler monkey (*Alouatta seniculus* L.), now have management plans that are based on research conducted by Fundación EcoAndina–WCS on population status, habitat requirements, and availability, as well as their current distribution through their geographic and ecological ranges (Kattan & Valderrama, 2006; Valderrama & Kattan, 2006). The management plans have geographically explicit conservation goals with assessment of direct and indirect threats. The plans also contain a sociopolitical analysis with opportunities for carrying out the proposed activities.
3. Development of preliminary management plans for 18 additional vertebrate species in one of the provinces (Valle del Cauca) for which less information is available. These species include the multicolored tanager (*Chlorochryssa nitidis-*

sima Scatter), which is endemic to west-central Colombia, and the pacarana (*Dinomys branickii* Peters), a unique Andean rodent.

4. Updating of management plans for already-established protected areas and their surrounding landscapes. In the case of the Otun watershed, the management plan was expanded to a regional scale. Two corporations (CVC and CARDER) have commissioned research projects to produce information for the updating of management plans.

These processes involved the incorporation of conservation biology concepts ranging from island biogeography and fragmentation to metapopulation ecology and habitat restoration. This was accomplished through a series of workshops in principles of conservation biology that apply to the design of networks of protected areas and through the production of educational materials (e.g., Kattan & Naranjo, 2008). In addition, GIS technicians from all of the participant government organizations received training on satellite image analysis and classification.

An offshoot of this process was the transference of science to other regional planning exercises in Colombia. One example is the Sistema Departamental de Áreas Protegidas (SIDAP) Sonsón, a province-level network of protected areas for the southern portion of Antioquia. Here, government organizations led the process, using the SIRAP-EC as a template, and EcoAndina–WCS assisted the process by preparing a habitat model for the spectacled bear (*Tremarctos ornatus* F. G. Cuvier, the animal with the largest habitat requirements), which served as a planning tool to define conservation priorities.

CASE STUDY 3: CONSORTIUMS OF ORGANIZATIONS THAT PROMOTE COMMUNICATION: THE CASE OF REDBIO

A third model that has proved successful in transferring science to practice is Red de Investigación en Biodiversidad y Conservación (REDBIO), which is a consortium of 25 organizations including national and regional government organizations, NGOs, and universities from western Colombia that was created in 2002. The consortium's main objectives are to promote communication, share experiences, and foster research and conservation projects. In its six years of activity, REDBIO has organized annual regional symposia on research and conservation of biodiversity. These symposia provide a showcase for ongoing research conducted in the region and are well attended by local researchers, NGOs, and protected area managers. REDBIO has also organized several courses and joined forces with Universidad de Antioquia, Colombia, to offer a graduate degree in protected areas for staff from

parks, corporations, and NGOs. In addition, all partner organizations collectively compile a database on regional biodiversity that is accessible to all.

FACILITATION IS THE KEY: THE ROLE OF INDIVIDUALS AND NGOS

The current transfer of science in Colombia is happening as a result of changes in the human and institutional dimensions. There is now a synergistic partnership between the government and NGOs. Government organizations have discovered the benefits that result from these partnerships and are increasingly engaging those in academia and civil society as advisors and contributors to the planning processes. This development is due in part to a number of highly committed individuals who, through their careers, have moved between government organizations, NGOs, and academia; because of their professional experience and mobility, they have created networks of connections in which they act as mobile links.

A key element in this synergism is the emergence of local, science-oriented NGOs that generate original research and usually work in collaboration with conservation agencies. These NGOs conduct research that addresses conservation needs. Although they face several of the same challenges as academics when it comes to raising funds, they are less pressured to publish in prestigious international journals. Thus, they have more freedom to choose their research questions and to focus on those that are most relevant to local conservation. They also produce materials that synthesize current knowledge on certain issues, and by participating in planning and other conservation action processes, they assist in the transfer of science to the government agencies. These NGOs are sensitive to local needs and have the flexibility to adapt their agendas to serve those needs. They are also committed in the long-term to sites or regions, and this allows them to collect data over a long period. This commitment is vital for understanding the responses of ecosystems and species to stressors and to monitor the impact of management practices. However, NGOs depend on money from grants and donors, which makes them fragile (Dour-ojeanni, 2006). Therefore, special efforts should be placed on strengthening national NGOs, because they can play a significant role in improving the transfer of basic science into actual conservation practice.

CONCLUSIONS

Environmental problems abound, and some are already sufficiently advanced to create effects of global proportions. Therefore, conservation practice must make use of all the information available to

curtail and potentially reverse the negative effects of human practices. This huge task cannot fall on the shoulders of scientists or managers alone. It requires an integrated approach in which all parties involved—governments, scientists, NGOs, donors, the media, scientific journals, and the general public—join forces to ensure that the relevant information is generated and applied in creative and bold ways.

Elsewhere, there are already a number of different mechanisms in place that allow the application of science to decision making, planning, and implementation of conservation (e.g., the Science and Technology Awareness Network of Canada). These mechanisms can be adapted and should be disseminated throughout the developing world. To do so requires strengthening organizations, particularly those at the national level, that are already serving as translators of science into practice, fostering the creation of new organizations that can serve in this role, mandating governments to incorporate science into their work, and further involving NGOs and academia in planning and decision-making processes.

Notwithstanding, there is a need for government organizations to strengthen their own staff so that they can directly access and apply science. To the extent that government officers embrace the notion that it is important to apply scientific evidence and methodologies to their decisions, the transfer of this science will occur more frequently and effectively. This will only happen when there is a minimal, basic level of understanding of how science can be applied within these organizations.

Although budgetary restrictions are a constant in government organizations in developing countries, local experience shows that even small investments can produce valuable information. In addition, communication among those who generate the science and those who should apply it requires little monetary investment and can yield impressive returns.

Literature Cited

- Aarssen, L. W., T. Tregenza, A. E. Budden, C. J. Lortie, J. Koricheva & R. Leimu. 2008. Bang for your buck: Rejection rates and impact factors in ecological journals. *Open Ecol. J.* 1: 14–19.
- Armstrong, D. P. & M. A. McCarthy. 2007. Big decisions and sparse data: Adapting scientific publishing to the needs of practical conservation. *Avian Conserv. Ecol.* 2: 14. <<http://www.ace-eco.org/vol2/iss2/art14/>>, accessed 5 May 2009.
- Chapman, C. A., R. W. Wrangham, L. J. Chapman, D. K. Kennard & A. E. Zanne. 1999. Fruit and flower phenology at two sites in Kibale National Park, Uganda. *J. Trop. Ecol.* 15: 189–211.
- Chazdon, R. L., S. G. Letcher, M. van Breugel, M. Martínez-Ramos, F. Bongers & B. Finegan. 2007. Rates of change in tree communities of secondary Neotropical forests following major disturbances. *Philos. Trans. Ser. B* 362: 273–289.
- Dourojeanni, M. J. 2006. ¿Organizaciones no gubernamentales internacionales o “transnacionales”? *Ecol. Aplic.* 5: 157–166.
- Eagle, K. A., A. J. Garson Jr., G. A. Beller & C. Sennett. 2003. Closing the gap between science and practice: The need for professional leadership. *Health Affairs* 22: 196–201.
- Gibbons, M., C. Limoges, H. Nowotny, S. Schwartzman, P. Scott & M. Trow. 1994. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*. Sage Publications, London.
- Groves, C. R. 2003. *Drafting a Conservation Blueprint: A Practitioner’s Guide to Planning for Biodiversity*. Island Press, Washington, D.C.
- Guariguata, M. R. 1998. *Consideraciones Ecológicas sobre la Regeneración Natural Aplicada al Manejo Forestal*. CATIE, Turrialba, Costa Rica.
- & R. Ostertag. 2002. Sucesión secundaria. Pp. 591–623 in M. R. Guariguata & G. H. Kattan (editors), *Ecología y Conservación de Bosques Neotropicales*. Libro Universitario Regional, Cartago, Costa Rica.
- Johnson, B. L. 1999. The role of adaptive management as an operational approach for resource management agencies. *Conserv. Ecol.* 3: 8. <<http://www.consecol.org/vol3/iss2/art8/>>, accessed 5 May 2009.
- Kattan, G. 2005. Planificando el Edén: Principios fundamentales en el diseño de sistemas regionales de áreas protegidas. Pp. 51–80 in N. Arango (editor), *Bases para el Diseño de Sistemas Regionales de Áreas Protegidas*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá.
- . 2006. Reconciling theory and practice in designing a regional reserve system: A Colombian case study. Pp. 548–550 in M. J. Groom, G. K. Meffe & C. R. Carroll (editors), *Principles of Conservation Biology*. Sinauer Associates, Sunderland, Massachusetts.
- & C. Murcia. 2001. *Desarrollo de una Estrategia de Investigación en Biología de la Conservación en el Sistema de Parques Nacionales Naturales*. Unidad de Parques Nacionales de Colombia, Bogotá.
- & C. Valderrama (editors). 2006. *Plan de Conservación de la Pava Caucana (Penelope perspicax)*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt and Fundación EcoAndina/Wildlife Conservation Society, Bogotá.
- & L. G. Naranjo. 2008. *Regiones Biodiversas: Herramientas para la Planificación de Sistemas Regionales de Áreas Protegidas*. Wildlife Conservation Society, EcoAndina, and World Wildlife Fund, Cali, Colombia.
- Kremen, C. 2005. Managing ecosystem services: What do we need to know about their ecology? *Ecol. Lett.* 8: 468–479.
- Lawler, J. J., J. E. Aukema, J. B. Grant, B. S. Halpern, P. Kareiva, C. R. Nelson, K. Ohleth, J. D. Olden, M. A. Schlaepfer, B. R. Silliman & P. Zaradic. 2006. Conservation science: A 20-year report card. *Frontiers Ecol. Environm.* 4: 473–480.
- Lubchenco, J. 1998. Entering the century of the environment: A new social contract for science. *Science* 279: 491–497.
- Manning, P. 2005. Bridging the communications gap between the science and non-science worlds. Science and Technology Network Conference, Toronto, Canada. <<http://www.scienceandtechnologynetwork.ca/main/downloads/Preston.pdf>>, accessed 5 May 2009.
- May, R. M. 1998. The scientific investment of nations. *Science* 281: 49–51.
- Meffe, G. K. 2006. The success—and challenges—of conservation biology. *Conserv. Biol.* 20: 931–933.

- Meijaard, E. & D. Scheil. 2007. Is wildlife research useful for wildlife conservation in the tropics? A review for Borneo with global implications. *Biodivers. Conserv.* 16: 3053–3065.
- Mills, T. J. & R. N. Clark. 2001. Roles of research scientists in natural resource decision-making. *Forest Ecol. Managem.* 153: 189–198.
- Newstrom, L. E., G. W. Frankie, H. G. Baker & R. K. Colwell. 1994. Diversity of long-term flowering patterns. Pp. 142–160 *in* L. A. McDade, K. S. Bawa, H. A. Hespenhide & G. S. Hartshorn (editors), *La Selva: Ecology and Natural History of a Neotropical Rain Forest*. University of Chicago Press, Chicago.
- Olden, J. D. 2007. How do ecological journals stack up? Ranking of scientific quality according to the h index. *Ecoscience* 14: 370–376.
- Pendergast, J. R., R. M. Quinn & J. H. Lawton. 1999. The gaps between theory and practice in selecting nature reserves. *Conserv. Biol.* 13: 484–492.
- Pullin, A. S., T. M. Knight, D. A. Stone & K. Charman. 2004. Do conservation managers use scientific evidence to support their decision-making? *Biol. Conserv.* 119: 245–252.
- Roux, D. J., K. H. Rogers, H. C. Biggs, P. J. Ashton & A. Sergeant. 2006. Bridging the science–management divide: Moving from unidirectional knowledge transfer to knowledge interfacing and sharing. *Ecol. Soc.* 11: 4. <<http://www.ecologyandsociety.org/vol11/iss1/art4>>, accessed 5 May 2009.
- Ruth, J. M., D. R. Petit, J. R. Sauer, M. D. Samuel, F. A. Johnson, M. D. Fornwall, C. E. Korschgen & J. P. Bennett. 2003. Science for avian conservation: Priorities for the new millennium. *Auk* 120: 204–211.
- Stinchcombe, J., L. C. Moyle, B. R. Hudgens, P. L. Bloch, S. Chinnadurai & W. F. Morris. 2002. The influence of the academic conservation biology literature on endangered species recovery planning. *Conserv. Ecol.* 6: 15. <<http://www.consecol.org/vol6/iss2/art15>>, accessed 5 May 2009.
- Stone, D. 2002. Using knowledge: The dilemmas of ‘bridging research and policy.’ *Compare* 32: 285–296.
- Valderrama, C. & G. Kattan (editors). 2006. Plan de Conservación del Mono Aullador (*Alouatta seniculus*) en la Región del SIRAP-EC y Valle del Cauca. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt and Fundación EcoAndina/Wildlife Conservation Society, Bogotá.
- Walters, C. J. & C. S. Holling. 1990. Large-scale management experiments and learning by doing. *Ecology* 71: 2060–2068.
- Whitten, T., D. Holmes & K. MacKinnon. 2001. Conservation biology: A displacement behavior for academia. *Conserv. Biol.* 15: 1–3.